Treatment of Abdominal Aortic Aneurysm by Excision and Replacement by Homograft

By Henry T. Bahnson, M.D.

Fourteen patients with arteriosclerotic aneurysm of the abdominal aorta are described. Excision of the aneurysm and reconstruction by an aortic homograft have been used in all cases. One patient from whom a ruptured aneurysm was excised, died after operation of uremia. Two other patients died of coronary artery disease after leaving the hospital. The remaining patients are well. Early results with this form of treatment are significantly better than those obtained by less definitive methods used in the past.

RECENT experiences with the treatment of saccular aneurysms of the aorta have shown that excision of an aneurysm in any portion of the aorta, with aortic suture, is feasible and that operative risk is not great.

Aneurysms of the distal abdominal aorta are in a more favorable position for surgical attack; however, such lesions are almost always caused by arteriosclerosis. The generalized distribution of the causative disease, the age of most persons affected, and the variable prognosis of untreated patients all indicate a more cautious approach in the application of excision in the treatment of arteriosclerotic aneurysms of the abdominal aorta. Nevertheless, the early results with excision of the aneurysm and replacement by homograft are encouraging and seem to establish this as a method of choice when operative treatment is indicated. This paper is a review of the first 14 patients treated by this procedure.

The great majority of aortic aneurysms are caused by either syphilis or arteriosclerosis. Occasional aneurysms caused by trauma or bacterial infection resemble in most respects those caused by syphilis. Syphilitic aneurysms are found most commonly in the thoracic aorta and predominantly in the ascending arch; they occur in younger persons usually less than 55 years of age; they are largely saccular aneurysms resulting from a localized rupture. Arteriosclerotic aneurysms, on the other hand, almost invariably occur in the terminal aorta below the origin of the renal arteries. As with other manifestations of arteriosclerosis, the lesion is more common in males and occurs in the older age group, the average age being around 65 years. Most arteriosclerotic aneurysms are fusiform, eccentric dilatations with elongation and thinning of most of the circumference. They rarely produce erosion of the vertebral bodies. The reason for the characteristically different location of syphilitic and arteriosclerotic aneurysms is not clear; however, the almost invariable localization of arteriosclerotic aneurysms in that portion of the aorta distal to the renal arteries is a fortunate feature from the surgical point of view.

The relative incidence of syphilitic and arteriosclerotic aneurysms varies with the prevalence of syphilis in any community. Likewise it is to be expected that in the future the frequency of syphilitic aneurysms will diminish because of the better control of syphilis, whereas that of arteriosclerotic aneurysms will increase with the increased duration of human life. At Hahnemann Hospital in Philadelphia, Maniglia and Gregory have shown that the number of aortic aneurysms per thousand autopsies has remained relatively constant since 1906, but that the ratio of arteriosclerotic to syphilitic aneurysms has increased from 1 to 8 between 1906 and 1931 to 2½ to 1 between 1949 and 1951.

CLINICAL FEATURES

The clinical characteristics of this group of patients are presented in table 1. All of the 14 patients had been aware of abdominal throb-
buling and a mass. Most of them had a sense of fullness in the abdomen. In no instance was throbhoing or fullness a distressing complaint. One half of the patients had significant pain which was attributed to the aneurysm and which has been relieved by excision of the lesion; in six of the seven the pain was associated with loss of weight or necessitated the use of narcotics. The pain was usually described as a steady deep ache, sometimes throbbing; it was not related to bending or straining, although frequently worsened or relieved by varying positions. The pain was usually referred to the midabdomen, although in some it has been entirely localized to the low back with radiation down the thighs. Pressure on the aneurysm has frequently elicited similar pain. The two patients observed after rupture of an aneurysm complained of severe pain; only one had pain before rupture. Seven patients had no pain at the time of hospitalization, although in five of these pain had previously been a significant complaint. Two patients (J. R. and M. A.) experienced an initial sudden pain in the abdomen at a time when the aneurysm probably first appeared. Patient J. R., a carpenter, was struck in the abdomen by a brace as the bit broke through a plank. An abdominal mass appeared which had not been noted during an examination for insurance two weeks before. The mass was tender and associated with moderate gastrointestinal hemorrhage. At operation the aneurysm was sharply delimited and there was only moderate arteriosclerosis in the adjacent vessel. This is the only patient in this group who had a definite history of causative trauma. In nine patients the asymptomatic aneurysm was discovered during examination for other reasons; in six of these nine patients symptoms appeared later.

**DIAGNOSIS**

Although aneurysms have been confused with almost every intra-abdominal and retroperitoneal lesion, the diagnosis is usually not difficult. On the other hand, the mere presence of a pulsating hard abdominal mass is not diagnostic, and other possible diagnoses must be eliminated. The expansile nature of the pulsation has been given as an important diagnostic feature; some authors have suggested attaching semaphores to the abdominal wall to observe separation of the tips with expansion. One only need see aortograms of these patients to realize the fallacy of this point, for most of the aneurysmal enlargement is filled with inelastic clot and the lumen is nearly normal.

Of much more value in diagnosis is the presence of a rim of calcium in the wall of the aneurysm, often well seen in the lateral or supine roentgenogram. In no instance in this series of arteriosclerotic aneurysms have vertebrae been found to be eroded. In doubtful cases aortography is useful for diagnosis as well as for evaluation. In one patient, F. S., the diagnosis could not have been made preoperatively without the aid of aortography. This patient had been extensively studied because of abdominal pain. Upon abdominal exploration elsewhere,* with a tentative diagnosis of pancreatic carcinoma, an aneurysm was found and an aortogram made. He was later referred to the author for definitive therapy. Even when the diagnosis was known the mass could not be felt in the unanesthetized patient.

The author has found aortography to be helpful although not essential. The information thus gained concerning the level and the extent of the aneurysm, the presence or absence of clot, and the size of the aortic and iliac arterial lumina are of importance in evaluating the indications for operation and in predicting the extent of excision required. General anesthesia with Pentothal and sometimes nitrous oxide has been used for this diagnostic procedure; the contrast medium employed was either Urokon or Diodrast injected through a long needle into the aorta. No significant difficulties were experienced with this procedure in this small group of patients.

**PROGNOSIS**

The prognosis for patients with untreated arteriosclerotic aneurysm is poor. The best study of this aspect is that of Estes.* He reported 102 patients with an abdominal aneu-
rlysm, 97 of which were attributed to arteriosclerosis, and three additional ones were caused by arteriosclerosis associated with syphilis. Survival in this group was compared with life expectancy of the normal population of the same mean age. Whereas 35 per cent of that portion of the normal population which is 65 years of age will die within eight years, 33 per cent of Estes’ patients with abdominal aneu-

Table 1.—Clinical Findings and Surgical Procedures in 14 Patients with Abdominal Aortic Aneurysm

<table>
<thead>
<tr>
<th>Age</th>
<th>Sex</th>
<th>Known Duration</th>
<th>History</th>
<th>Complications</th>
<th>Preoperative Lumen and Sac.</th>
<th>Operation and Date</th>
<th>Period of Occlusion, Minutes</th>
<th>Remarks and Follow Up Oct. ’53</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>69</td>
<td>M mass.</td>
<td>Asymptomatic, Mass noted at time of coronary infarction, recently enlarged.</td>
<td>Old coronary infarction.</td>
<td>2-14-53</td>
<td>110</td>
<td>Postoperative oliguria for 3 days. Now well.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>61</td>
<td>M mass.</td>
<td>Asymptomatic till 4 days before admission; then severe pain in abdomen and back.</td>
<td>Hypertension 220/110</td>
<td>3-13-53</td>
<td>125</td>
<td>Had been studied in 1952. Returned with early rupture. Now well except for hypertension.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>74</td>
<td>M mass and pain</td>
<td>Continuous pain in abdomen and back for 1 yr., with 15 lbs. weight loss. Asymptomatic for last 4 mo.</td>
<td>Amputation 1936 for Buerger’s disease; claudication in remaining leg. 2 prior coronary infarcts.</td>
<td>3-20-53</td>
<td>115</td>
<td>Postoperatively distal pulses weak, calf tenderness. Amputation done 6 mo. later for ulcer and atrophy. Otherwise well.</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>66</td>
<td>M mass.</td>
<td>Sudden onset after trauma; g.i. hemorrhage required laparotomy. Subsequently quiescent.</td>
<td>Good general health.</td>
<td>4-13-53</td>
<td>70</td>
<td>Uncomplicated recovery. Excellent health now.</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>70</td>
<td>M mass.</td>
<td>Increasing pain in abdomen, low back and right hip.</td>
<td>Hypertensive. Treated cardiac decompensation.</td>
<td>4-16-53</td>
<td>60</td>
<td>Ureter divided inadvertently and repaired. Loose clot in aneurysm probably dislodged. Bilateral amputations. Fatal acute myocardial infarction 6 mo. later</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>77</td>
<td>M mass.</td>
<td>Fullness, throbbing, increasing size.</td>
<td>Treated peptic ulcer. Good health.</td>
<td>4-24-53</td>
<td>70</td>
<td>Rapid recovery. Excellent health now.</td>
<td></td>
</tr>
</tbody>
</table>

* Negro
in the first year after being seen, and half will die within eight years (fig. 1). If this cause of death can be excluded, the death rate from other causes is only slightly higher than that of the normal population.

The prognosis for an individual patient cannot be accurately predicted on the basis of any known sign or symptom. Pain is not reliable, as an aneurysm may be painless prior to rupture, and some painful aneurysms may exist for several years without change. In some instances severe pain has ceased without treatment or apparent change in the aneurysm.

**METHODS OF TREATMENT**

Numerous methods have been used in treatment of aortic aneurysm. Those of more than passing interest may be grouped under the following headings: use of fibrogenic or reinforcing materials about the aneurysm, intro-

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<tr>
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*Negro
Excision of Aortic Aneurysm

Fig. 1. Data obtained from Estes.\(^3\) Upper curve and figures are from follow-up of 102 patients with abdominal aneurysms. Lower curve is estimated from life insurance data. Middle curve computed from top curve and Estes observation that of 49 patients in whom the cause of death was determined, 63.3 per cent died of rupture of aneurysm. Middle curve is important one for estimation of prognosis of aneurysm itself.

1. Fibrogenic and reinforcing materials have been used widely in recent years, based upon Page's original use of cellophane about the kidney to produce hypertension.\(^4\) The active fibrogenic ingredient of this material has been shown by Yeager and Cowley\(^5\) to be dicetylphosphate. Methods have been described for obtaining a high concentration of this agent about the aneurysm.\(^6\) From experimental and clinical work performed here it seems probable that fibrogenic material placed around an aneurysm does not actually cause constriction with contraction but rather simply reinforces the wall with scar tissue. Assuming this to be true, the use of a porous material through which capillaries can grow offers advantages. Kirklin and associates reported 18 patients in whom the aneurysm was completely mobilized and the wall reinforced by a nonreacting polyvinyl sponge. Complete mobilization was often difficult, and survival with this treatment was no better than that of patients without operative treatment.\(^7\) There have been numerous single case reports of the successful treatment of aortic aneurysm by wrapping, but in larger series results are not encouraging when the variable prognosis without treatment is recalled.

2. Wiring as a method of treatment of aortic aneurysm has undergone many modifications since Moore first introduced it in 1864.\(^8\) One modern refinement of this method has been described by Blakemore and King; they used fine, insulated, coin-silver wire which could be heated after introduction into the aneurysm. Such wire attains a temperature which induces clotting only in those areas of the vascular channel where flow is not so rapid, thus producing a selective concentric clotting and reinforcing the peripheral or sacular components of the aneurysm.

3. Ligation would seem to be applicable only to those aneurysms which occur in the terminal aorta. The danger to the patient and to his extremities from abrupt ligation of the aorta is considerable. The need for gradual occlusion of the aorta has been recognized for many years, and numerous methods to bring this about have been developed, including Halsted's aluminum bands, elastic ligatures, repeated operations with progressively tighter constriction, and the use of fibrogenic material. Forty-five attempts to occlude the aorta by ligation were recorded prior to 1951.\(^9\) In none of the 21 instances recorded before 1918 did the patient survive. Since that time half of the patients so treated survived for six months and several for over a year. Blakemore devised a method for constriction of the aorta above the aneurysm, using an elastic band which he placed over fibrogenic polyethylene; he inserted wire into the aneurysm itself to induce clotting. This method of ligation was used in 33 instances. Those four patients in whom the aorta was completely obstructed obtained relief of pain and had no further progression of the aneurysm. When such a degree of constriction was not obtained the aneurysm remained a threat to the patient. Some patients with complete occlusion of the aorta, however, showed evidence of inadequate circulation to the lower extremities.\(^10\) Hence ligation, while feasible in many instances, is associated with considerable risk and aims at an end result which is not entirely desirable.

4. Endoaneurysmorrhaphy, as described by Matas,\(^11\) is an established procedure for treatment of aneurysm of peripheral arteries. Early
experiences with this method applied to the aorta were not successful, but recently Wiley,14 and Kirklin7 and their associates have combined this procedure with endarterectomy and removal of clot and diseased intima. Of four patients operated upon by Kirklin only two were alive 8 and 14 months, respectively, after operation. The additional step, as described by Kirklin, of reinforcing such a reconstructed vessel by fascia or polyvinyl sponge has not improved the poor results.

5. For patients with aortic aneurysm in whom surgical therapy is indicated, the author believes excision of the aneurysm to be the procedure of choice. The sharp localization of arteriosclerotic aneurysms to the distal aorta makes this lesion particularly accessible to excision and replacement by homograft. Arterial homografts have been used for numerous conditions, based upon their original use by Gross, Bill and Peirce14 in patients with congenital heart disease. Oudot described resection of the aortic bifurcation for thrombotic occlusion and replacement by homograft,15 Dubost first used a graft for reconstruction after excision of an abdominal aortic aneurysm.14 Numerous workers have since reported similar procedures.17 There is evidence, from both animal experiments and clinical use, that such homografts will continue functionally adequate considerably longer than the five-year period of follow-up now obtainable on Gross's first patient.18

EXCISION AND REPLACEMENT BY HOMOGRAFT

Operative Technic

General anesthesia has been used. Either a midline or a left paramedian incision extending from xiphoid to midway between umbilicus and pubis is satisfactory. The small intestines are displaced to the right and the posterior peritoneum incised over the aneurysm to the left of the base of the mesentery (fig. 2). The peritoneum usually can be readily dissected free. Before attempting mobilization of the aneurysm, tapes must be placed beneath the aorta and the iliac arteries so that bleeding may be controlled if necessary. During the dissection around the proximal aorta, care must be exercised that the renal arteries and left renal vein are not damaged. Similarly the iliac and hypogastric veins must be avoided when isolating the adjacent arteries. The ureters should be visualized and avoided. The inferiorter mesenteric artery is frequently found occluded, but one need have little fear of ligating it if it is patent.

As soon as the extent of the aneurysm and the condition of the iliac arteries distally can be determined, a homograft is selected and preparation of it begun. The graft used in case 1 was preserved at 4 C. in fluid as described by Gross, Bill and Peirce.14 All others were frozen and dried. The latter method is advantageous in that such grafts may be kept indefinitely and seem to be associated with less danger of thrombosis.19 Preparation of a frozen-dried graft usually requires 40 to 50 minutes, during which time further mobilization of the aneurysm from the vena cava and posteriorly can be done. This mobilization can best be performed after the aorta is divided and the aneurysm drawn forward (fig. 3). When excision is begun the aorta can be occluded with a curved Potts coarctation clamp, and the iliac arteries with rubbershod bulldog clamps or Potts ductus clamps. Despite care in dissecting the aneurysm from adjacent vena cava and iliac veins, these vessels have often been torn; the defects have been sutured with 5-0 arterial silk. It may be wiser to leave the wall of the aneurysm where it is intimately adherent. In this group of patients, however, a vigorous effort was made to remove the sac if possible because of
previous difficulties with infection in saccular aneurysms which were incompletely excised.\textsuperscript{1} A small portion of the aneurysm was left in only one patient.

An extremely important step is the instillation of approximately 10 mg. of heparin into each distal iliac artery as soon as it is occluded. This can be done by needle injection of concentrated solution or through a catheter inserted into the artery and withdrawn as soon as the instillation of a diluted solution is made. In several instances when this step was delayed, it was necessary to express thrombi from the distal segment. Thrombosis may occur down to the entrance of the first collateral artery if heparin is not used, and this thrombus might be flushed distally when the graft is opened. Such\textsuperscript{1} has apparently happened in three patients in this series.

The graft was sutured with 4-0 arterial silk to the aorta and 5-0 silk to the iliac arteries. Because of the short cuff of aorta proximally, the anastomosis was made as described by Blalock, by placing a posterior row of continuous evertting sutures which is pulled up when completed. The anterior portion and iliac anastomoses distally have been made with an over-and-over stitch through all layers (fig. 4). Competence of the proximal anastomosis can be tested by injection of saline into the graft through one iliac and additional sutures placed if required. In many instances the posterior row has been reinforced by a continuous over and over suture. When occlusion of the aorta is unduly prolonged one completed limb of a bifurcation graft may be opened, provided the remaining iliac is occluded at its origin to prevent thrombus formation in a short blind segment.

In all these patients the aorta was arteriosclerotic. This made anastomosis more difficult than in normal patients but not impossible. Frequently plaques were removed from the site of anastomosis before suturing was begun.

In elderly patients such as these one must follow fluid and electrolyte balance carefully in the postoperative period. Antibiotics were used to prevent infection. Gastric suction was employed to avoid the otherwise almost inevitable abdominal distention. No other precautions were taken in postoperative care. Early ambulation was urged and begun 24 to 48 hours after operation or as soon as the patient was willing.

\textbf{FIG. 3.} Aorta has been occluded with curved Pott's coartation clamp, divided, and the aneurysm drawn forward. Mobilization and dissection behind the aneurysm are much easier at this time than before division of the aorta. (Reproduced by permission of \textit{Annals of Surgery}.\textsuperscript{21})

\textbf{FIG. 4.} Reconstruction of aorta by homograft between aorta and common iliac arteries distally. (Reproduced by permission of \textit{Annals of Surgery}.\textsuperscript{21})
Results

An aneurysm of the terminal aorta has been excised and replaced by a homograft in 14 patients. The procedure was completed in each instance.

There have been three deaths thus far in the group of patients: one at four days, and one each at four and five months after operation. The first of these, W. K., was known to have an aneurysm which extended above the level of the renal arteries. He had been sent home awaiting procurement of a long bifurcation graft but returned in profound shock because of rupture of the aneurysm. Massive transfusion therapy was given and operation begun. By rapid and blunt dissection in the large hematoma the superior mesenteric artery and aorta proximal to the renal arteries were isolated and occluded with a single clamp. The aorta was divided just below the renal arteries and a graft was sutured in place; the suture line partly involved the mouths of the renal arteries. The graft was occluded and blood was allowed to perfuse the kidney after completion of this anastomosis while the two iliac anastomoses were completed; renal flow was shut off for 110 minutes. He was beginning to diurese on the fourth postoperative day when death occurred following uremic convulsions. Autopsy showed advanced nephrosclerosis. The right kidney was considerably hydronephrotic with obstruction of the upper ureter from an old hematoma caused by a previous small leak. Renal ischemia from preoperative shock and hurried occlusion of the leaking aorta undoubtedly caused severe damage to the diseased kidneys. This is the only instance in this group of patients in which the aneurysms extended above the renal arteries, and in this case the aneurysm was believed to be due to syphilis as judged by histologic examination.

The second death (patient J. T.) occurred four months after operation; it was due to progressive myocardial failure due to coronary artery disease. Gangrene of the left foot occurred in the early postoperative period and supracondylar amputation had been necessary.

The third death (patient J. K.) resulted from acute myocardial infarction six months after operation. Bilateral amputation had been performed because of ischemic necrosis shortly after the initial operation.

A distressing complication has been diminution of the circulation to the legs which occurred to a significant degree in three patients. One required bilateral and a second unilateral amputation during the immediate postoperative period as mentioned above. The third (G. B.) recently returned because of atrophy of the calf and ulceration on the foot; amputation was performed. It is believed that the cause of ischemic necrosis in all three patients was dislodgment of a thrombus which formed in the distal iliac artery during occlusion and insertion of the graft. In these patients heparin was not administered as described above. It is now believed that the use of heparin is essential. The aorta was occluded for the longest period in the last two patients in the group. No permanent impairment of peripheral circulation occurred, although one patient had had prior intermittent claudication and occlusion of both superficial femoral arteries. Lumbar sympathectomy has been done in several instances but but there is no evidence that it is of definite value.

Selection of Patients

During the period that this procedure has been employed, only two patients seen have been refused operation. One was in her late eighties and in shock from rupture of the aneurysm; she subsequently died. The second was 74 years old and free of symptoms; the aneurysm extended above the renal arteries as determined by aortography. A 70 year old man would not permit operative treatment. On the basis of experience with these patients and the expected survival as discussed earlier, the following criteria serve as guides in the selection of patients for operation.

Chronologic age is of much less importance than physiologic age, but a young person with an aneurysm has a greater likelihood of dying because of the aneurysm than an older one. Patients 70 years of age or over without symptoms should certainly not be urged into operation. Cardiac compensation, renal function and the presence of coronary artery disease must be more carefully evaluated in elderly patients.
Pain and abdominal discomfort are the prime indications for operation. At any age operation is probably justified if discomfort cannot be controlled without the use of narcotics. Under such circumstances relief of pain furnished by excision of the aneurysm justifies the risk to life and limb. Two patients, J. T. and G. B., in whom ischemic necrosis developed and who required amputation were nonetheless grateful because of relief from pain.

Rupture of the aneurysm is an indication for emergency operation. Frequently there is a period after initial leakage when the patient recovers temporarily before the retroperitoneal hematoma extends or secondarily ruptures. One patient (I. J.) survived operation for an early rupture. The single patient who died following excision of a ruptured aneurysm would undoubtedly have died without operation.

Finally, the author has relied to a small extent upon the aortographic examination, believing that there is more danger of rupture from an aneurysm with a large lumen and a thin wall than from an aneurysm in which a thick, laminated clot reduces the lumen to nearly normal. In addition, irregularities of the lumen may indicate areas of potential weakness. Aortography will demonstrate the rare aneurysm which extends above the renal arteries. Such an aneurysm can be largely excised and aortic anastomosis can be done at the level of the renal arteries, but this is associated with an increased risk.

SUMMARY

Fourteen patients with an abdominal aortic aneurysm have been treated by excision of the terminal aorta and replacement by homograft. One patient, in whom the renal blood flow had been occluded for 110 minutes, died of uremic convulsions four days after excision of a ruptured aneurysm. One patient died four months after operation of progressive myocardial failure due to coronary artery disease, and one died of coronary occlusion six months after operation. These last two and one additional patient required amputation because of ischemic necrosis. This was probably caused by lodgingment of a thrombus which formed in the distal iliac artery during occlusion of the homograft. Proper use of heparin during operation appears to prevent this complication.

The 11 surviving patients have remained in good health during the short periods of observation, which range from two to eight months.

Excision and replacement by homograft appears to be the procedure of choice for abdominal aortic aneurysm when surgical therapy is indicated.

ACKNOWLEDGMENTS

Patient I. J. was treated at The Marine Hospital, U. S. Public Health Service, Baltimore, with Dr. E. Converse Pai'rce, II. One of the frozen-dried grafts was obtained from the Tissue Bank, U. S. Naval Medical Center, Bethesda, Md.

SUMARIO ESPAÑOL

Catorce pacientes con aneurisma de la aorta abdominal han sido tratados por excisión de la aorta terminal y reemplazo con homoinjerto. Un paciente en el cual la circulación renal fue ocluida por 110 minutos, murió con convulsiones urémicas cuatro días después de la excisión de un aneurisma rupturado. Un paciente murió cuatro meses después de la operación de desfallecimiento progresivo del miocardio debido a enfermedad coronaria y uno murió de oclusión coronaria seis meses después de la operación. Estos últimos dos y un paciente adicional necesitaron amputación debido a necrosis isquémica. Esto se debió probablemente a desalojo de un trombo con origen en la arteria ilíaca distal durante la oclusión del homoinjerto. Uso apropiado de heparina durante la operación aparente evitar esta complicación. Los once pacientes sobrevivientes han permanecido en buena salud durante el corto período de observación, que data de dos a ocho meses. Excisión con reemplazamiento con homoinjerto aparece ser el procedimiento más indicado para aneurisma aórtico abdominal cuando el tratamiento quirúrgico es necesario.

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